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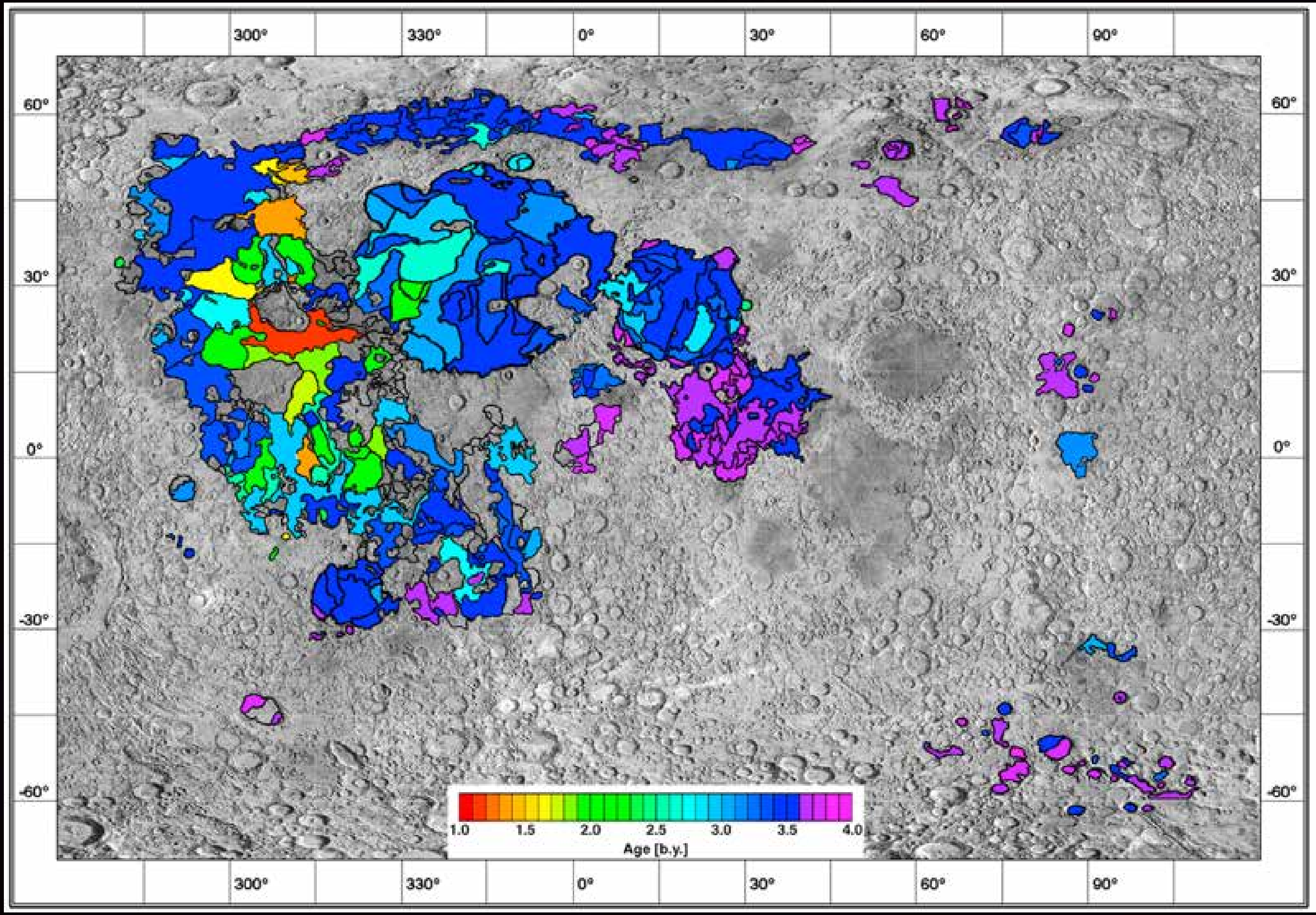
HGF-Alliance ROBEX
Robotic Exploration of Extreme Environments

ROBEX Moon Analog Mission: Scientific Questions

DR. MARTIN KNAPMEYER
DLR INSTITUTE OF PLANETARY RESEARCH

Scientific Rationale



Hiesinger et al., JGR 115, doi:10.1029/2009JE003380 (2010)

Scientific Rationale

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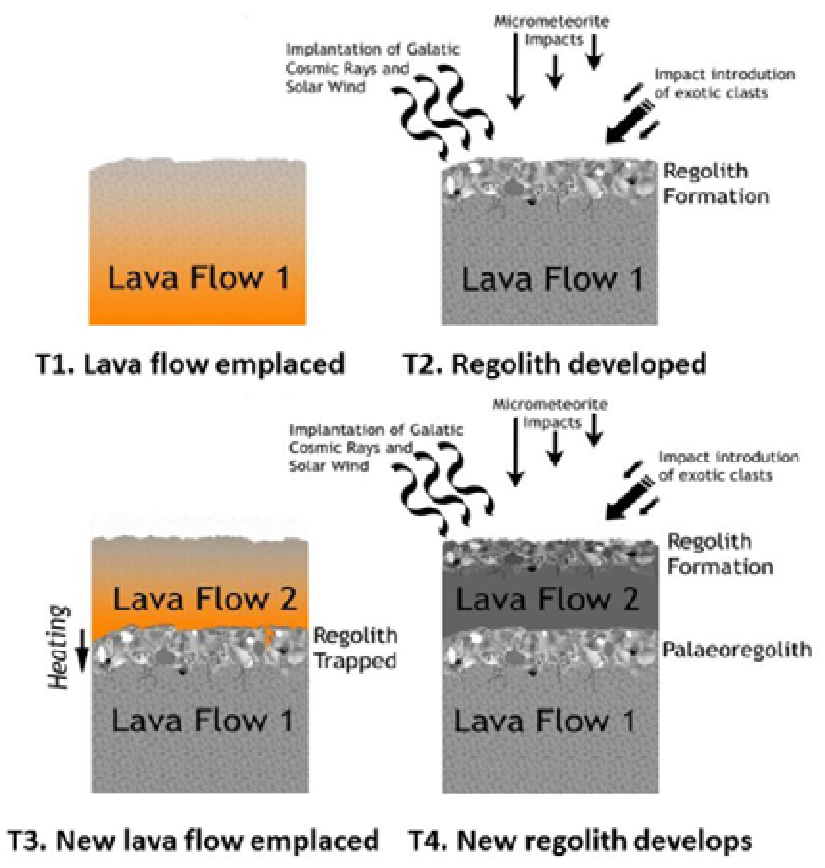

Figure 2. Schematic representation of the formation of a palaeoregolith layer (Crawford et al., 2007; Crawford and Joy, 2014): (T1) a new lava flow is emplaced, and meteorite impacts begin to develop a surficial regolith; (T2) solar wind particles, galactic cosmic ray particles and "exotic" material (possibly including supernova ejecta) are implanted; (T3) the regolith layer, with its embedded historical record, is buried by a more recent lava flow, forming a palaeoregolith; (T4) the process begins again on the upper surface (adapted from Crawford et al., 2007).

Lunar Palaeoregoliths as Recorders of Solar System History
A proposal submitted in response to the call for new scientific ideas in ESA's science programme
I. A. Crawford, L. Alexander, R. Jaumann, K.H. Joy, et al. (2016)

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Scientific Rationale

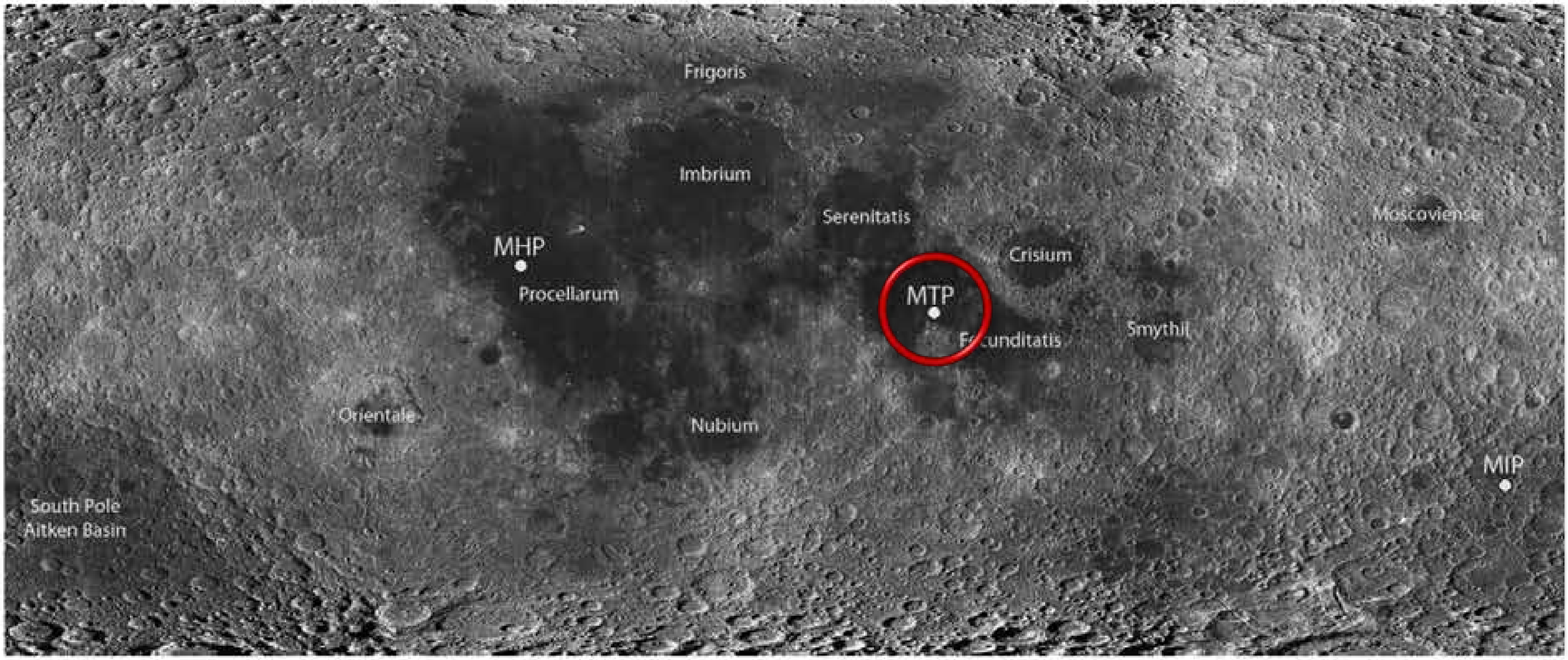
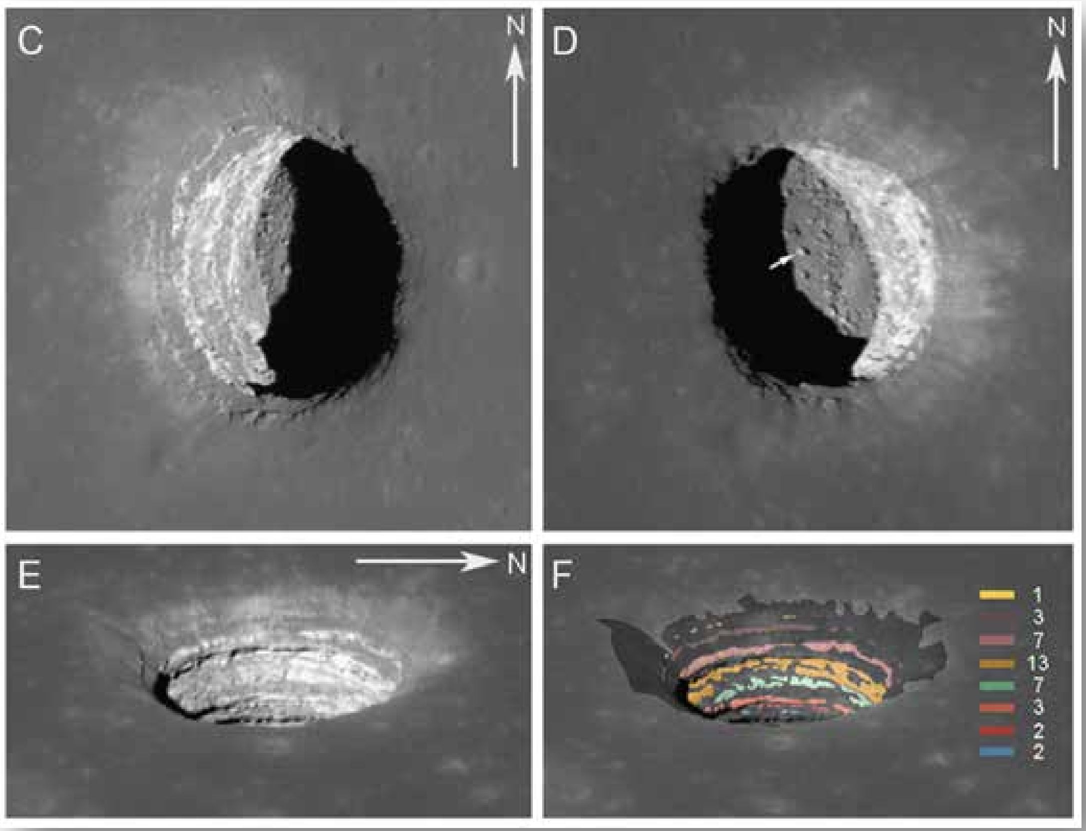


Fig. 1. LROC WAC mosaic showing locations of the three steep walled mare pits, area covers 180 °W to 180 °E longitude, and ±75° latitude. MHP Marius Hills Pit (14.091 °N, 303.223 °E), MTP Mare Tranquillitatis Pit (8.335 °N, 33.222 °E), MIP Mare Ingenii Pit (35.950 °S; 166.057 °E).

Scientific Rationale



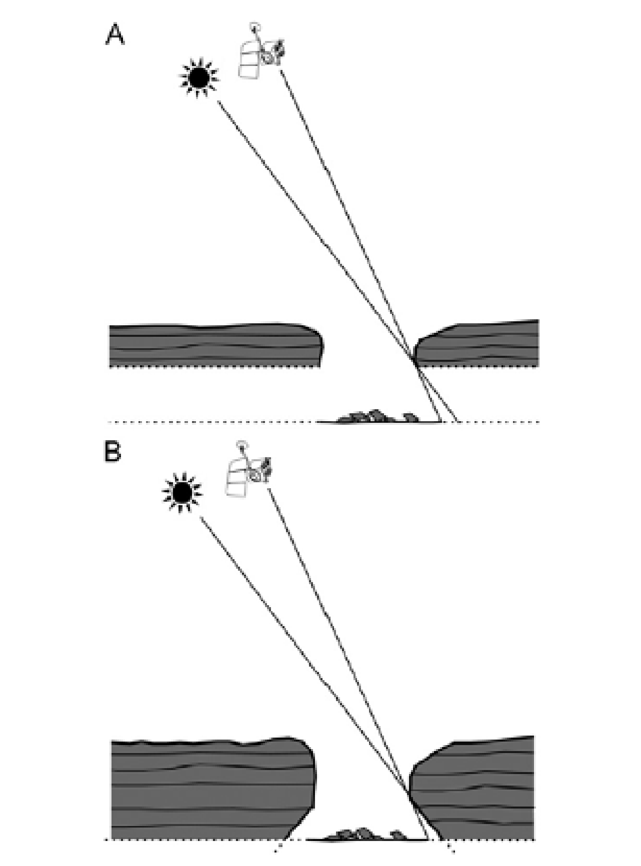
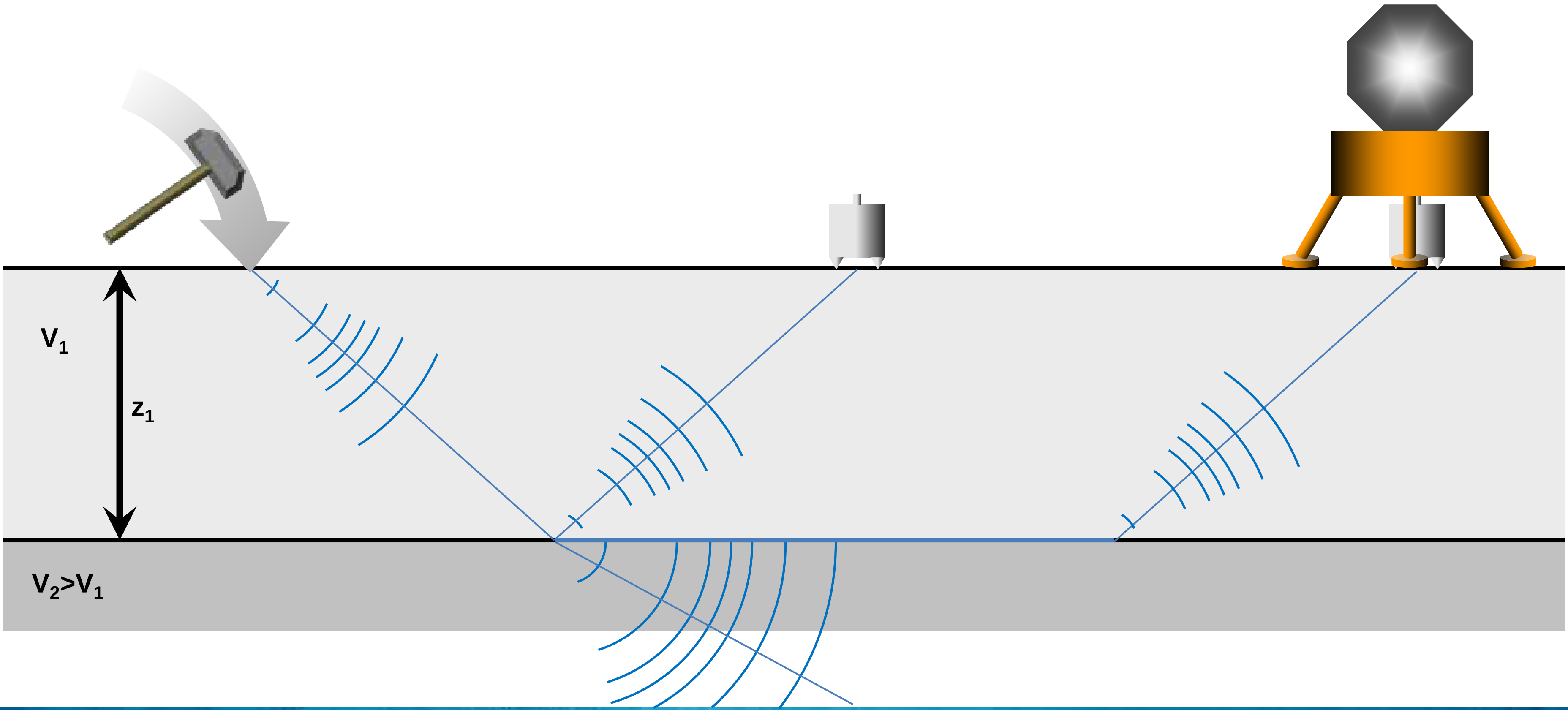


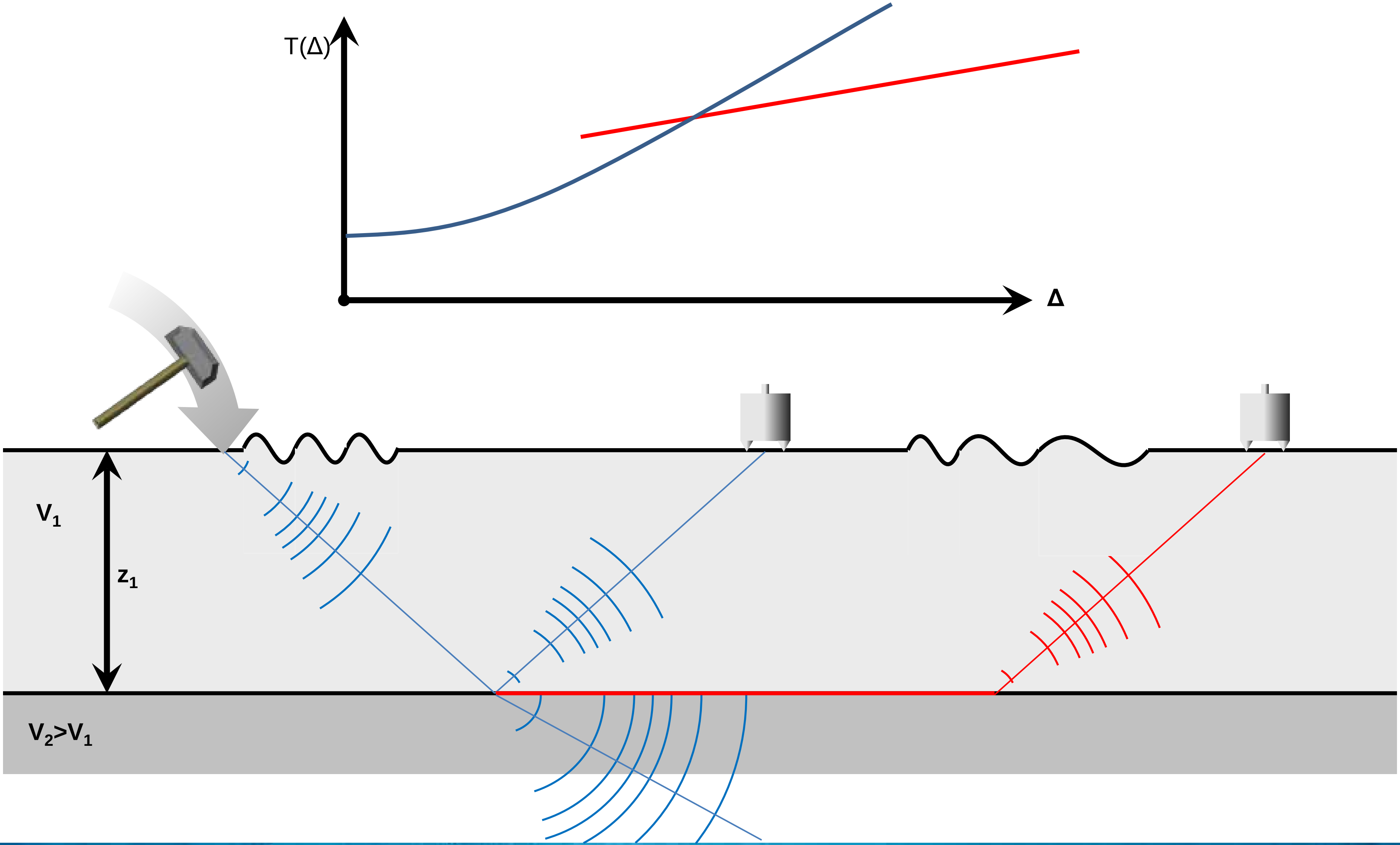
Fig. 6. Model of pit formation as (A) collapse into lava tube (skylight), and (B) collapse into near surface magma chamber resulting in an inverted cone shaped void. Dashed lines are speculative in both scenarios.

Robinson et al., PSS 69, 2012

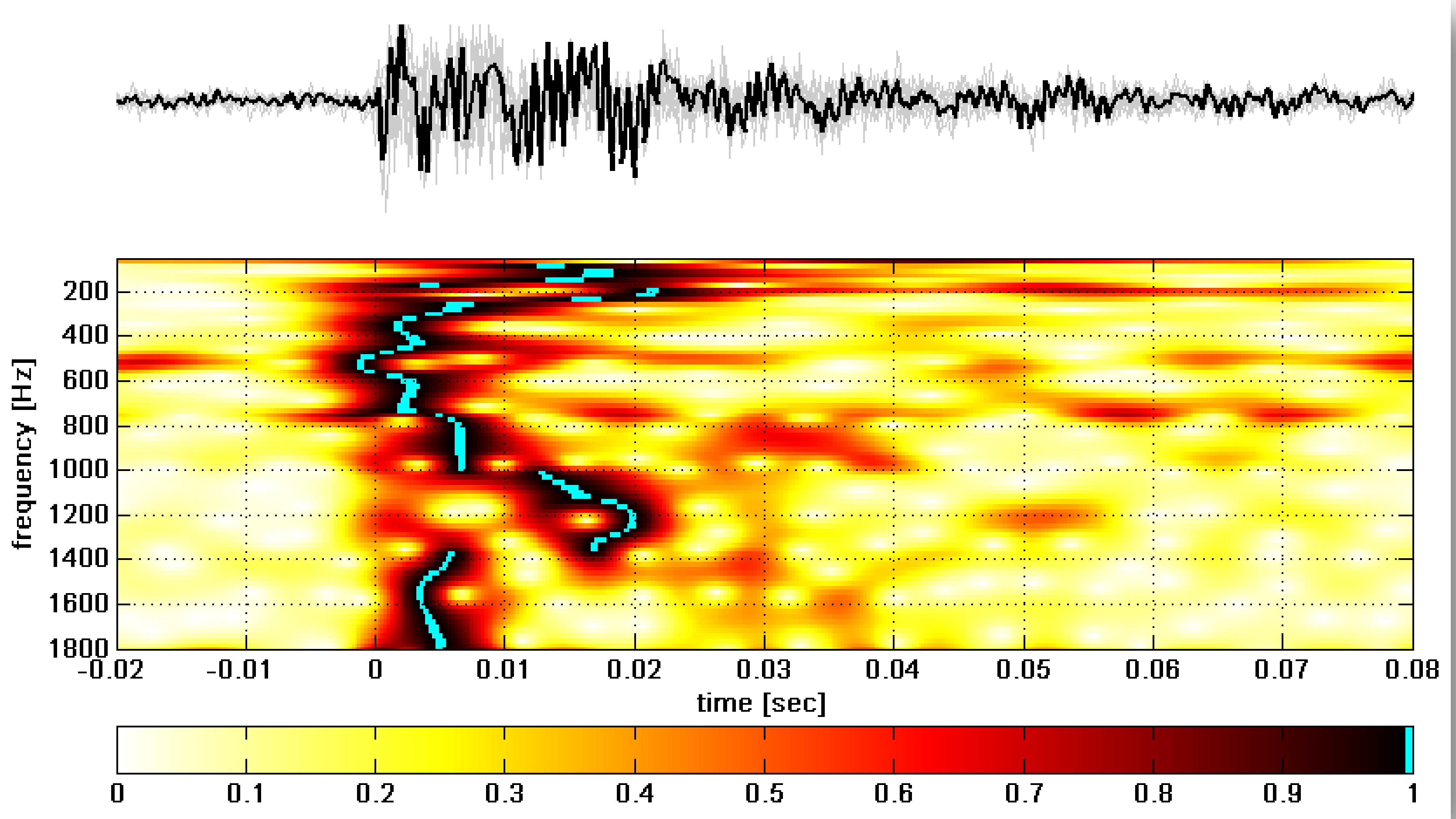
Method



Method

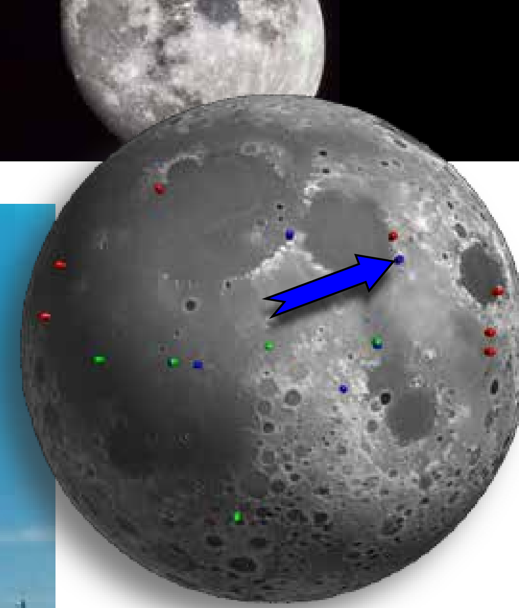


Churyumov-Gerasimenko



Knapmeyer et al., 2017, submitted to Icarus

Apollo 17



Apollo 17, Geophones 1 & 3

Video: Geophone deployment

Geophone 3 flag

2+40 CONFIG FOR PHOTOS/SAMPLING
Return to LRV
Config LRV Sampler (opt)
Get LMP cam
Get gnomon

2+49 LSPE GEOPHONE DEPLOY
Return to Geo Module
Remove & discard cover
Insert UHT in reel #3
Get flag
Get gnomon
Deploy Geo 3 88'S (Xsun)
Embed Geo & anchor w/flag
Emplace gnomon 2'NW of Geo 3
- Photo doc remaining Geo's as reqd if no LOS to Geo 3

Insert UHT in reel #1
Get flag
Deploy Geo 150'E (Upsun)
Embed Geo & anchor w/flag

GEOPHONES GEO PHOTO

LMP-22 EVA1 11-1-72

3+00 Insert UHT in reel #2
Get flag
Deploy Geo 2 150'W (Dnsun)
Embed Geo & anchor w/flag

Insert UHT in reel #4 [DEEP CORE
Get flag
Deploy Geo 4 260'S
Embed Geo & anchor w/flag

Return to Geo 3:
- Move 25'SW, photo Geo's 1/3, 2, 4
- Move 25'SE, photo Geo's 2/3, 1, 4
- Take pan 10' S of Geo 3

GNOMON TO C/S

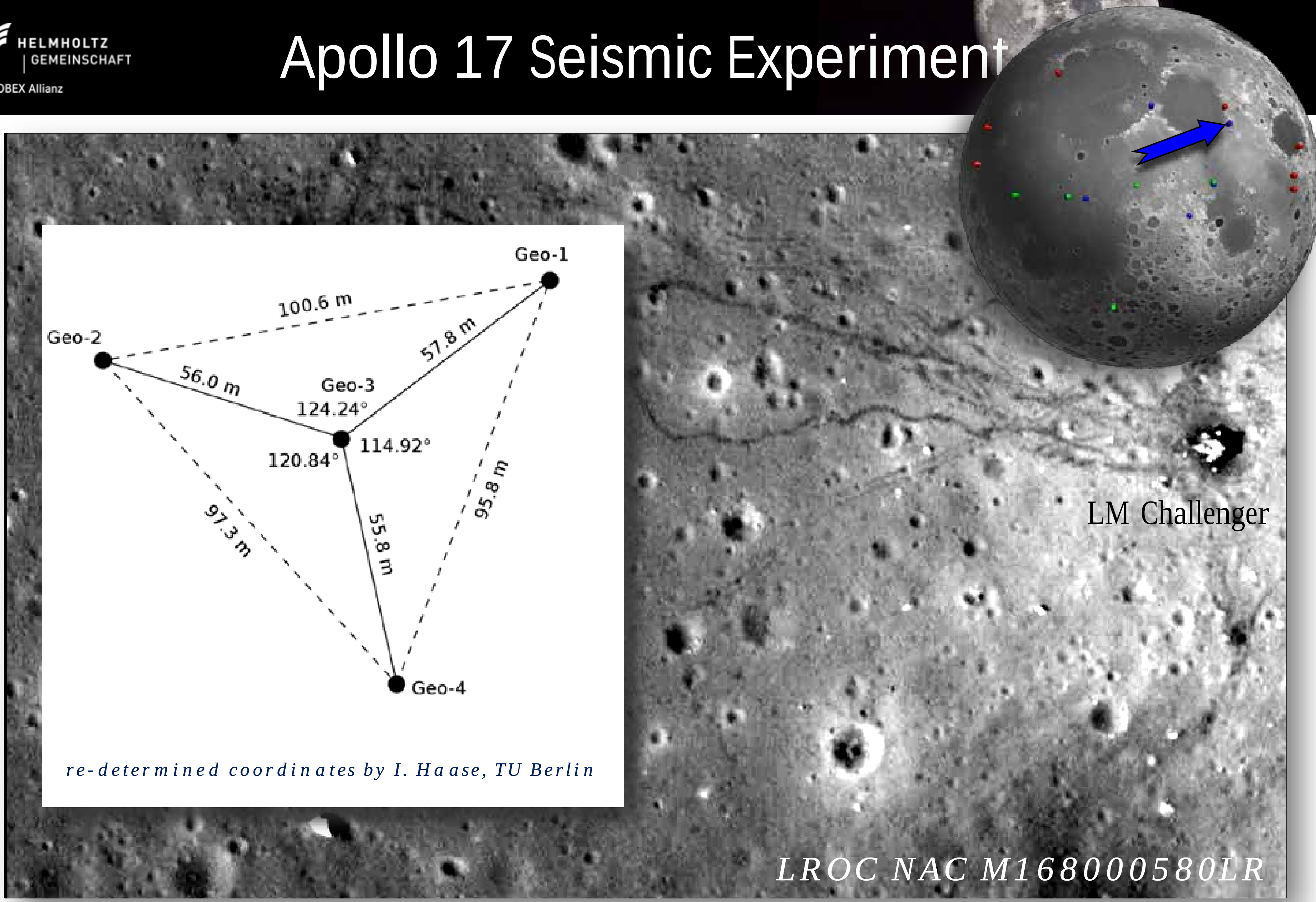
LMP-23 EVA1 11-1-72

GEOPHONES GEO PHOTO

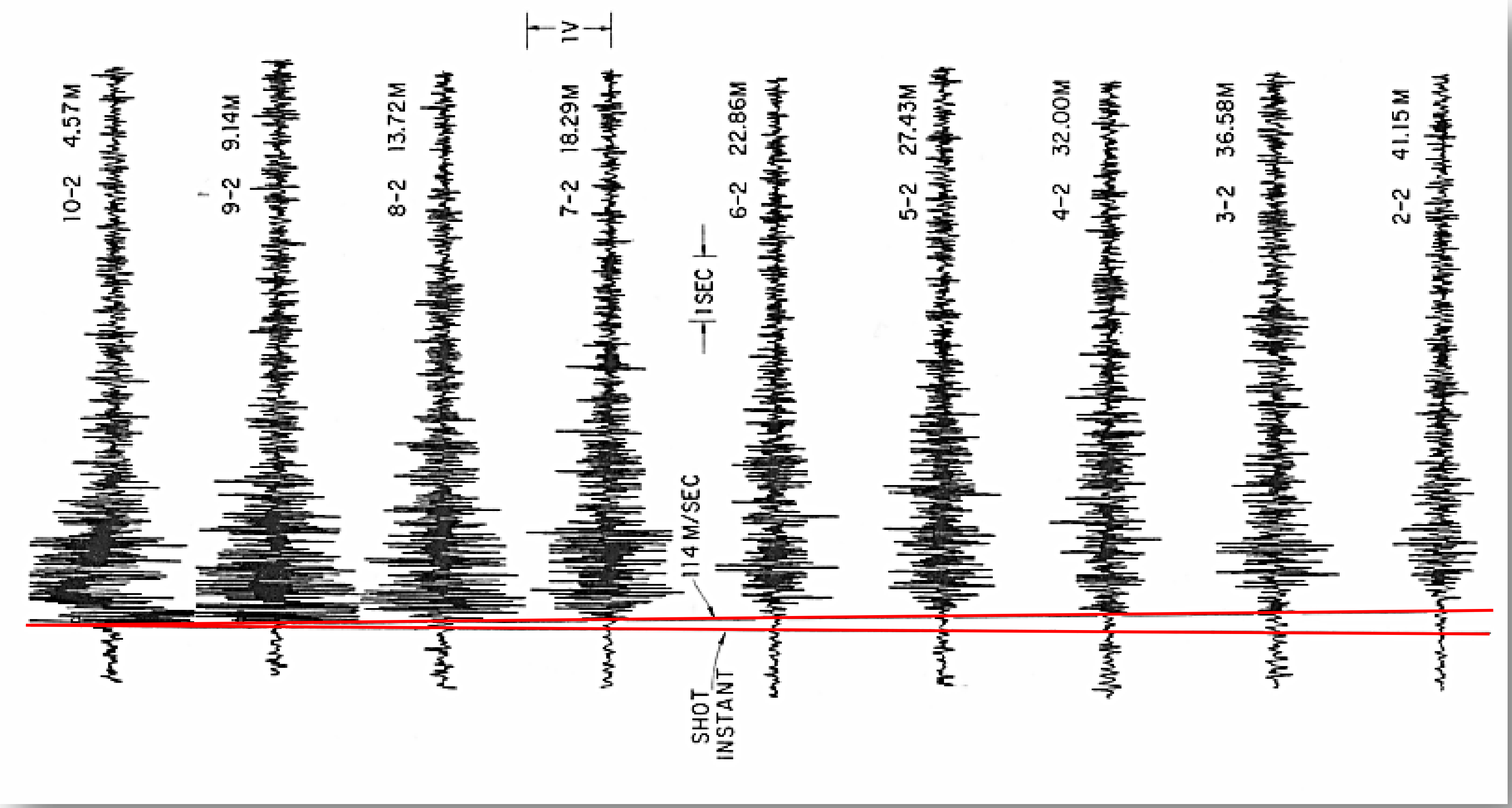
geophone 3 just deployed near "geophone rock"


search for predefined
pick up flag to mark
walk to geophone 1
struggle with cable reel

Apollo 17 Seismic Experiment



Apollo 16, Geophone Data

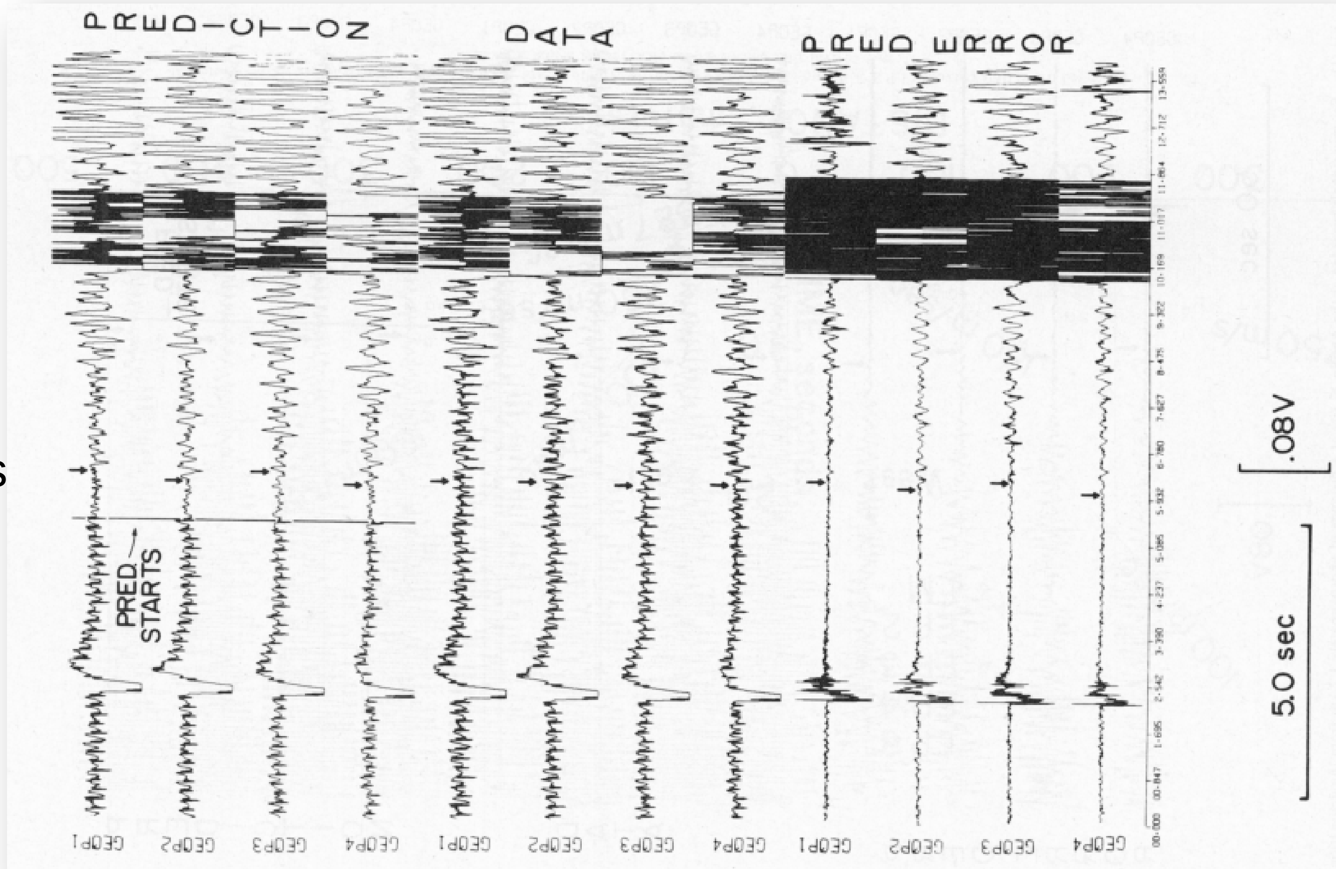


Cooper et al., 1974

Apollo 17, Geophone Data

arrivals

Firing time



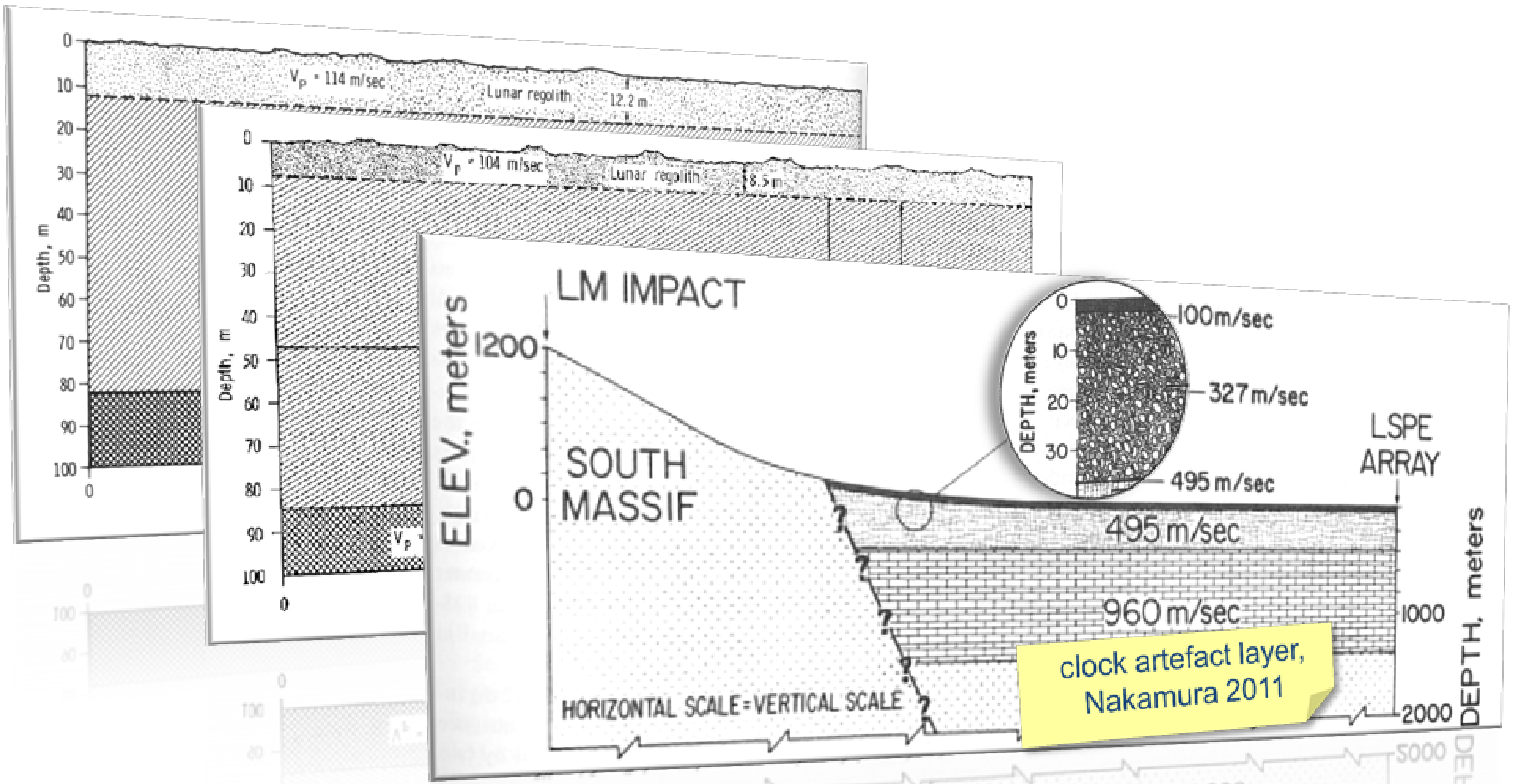
Noise prediction filter

Raw data

Prediction error filter

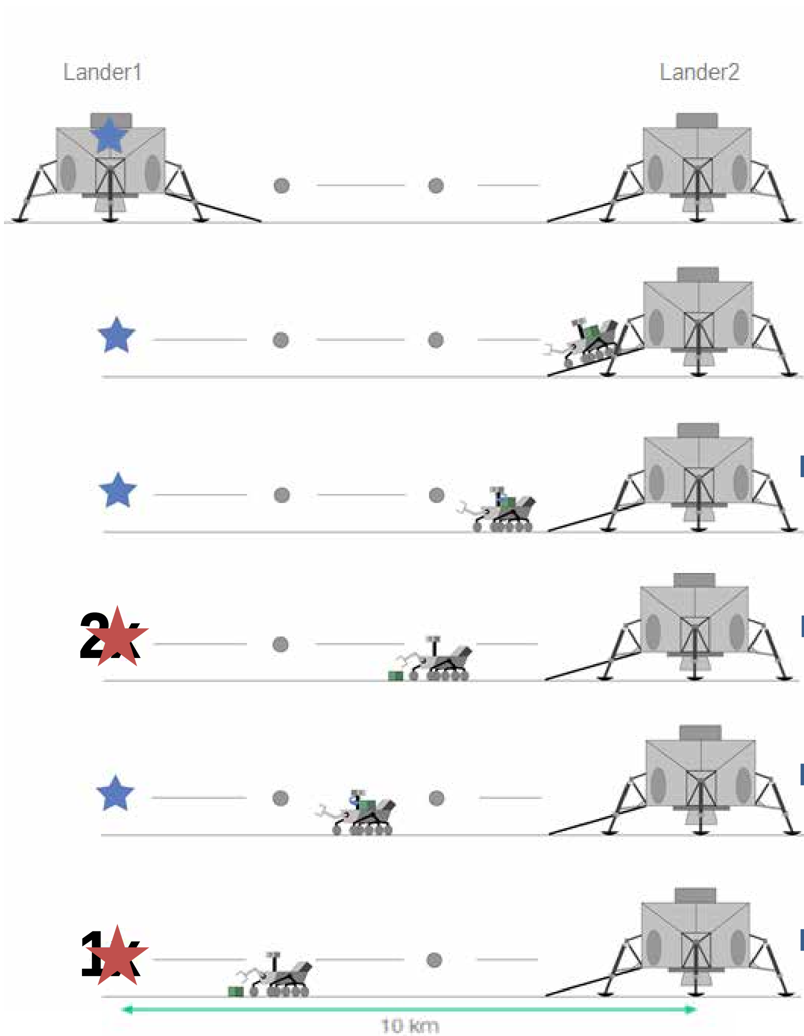
Cooper et al., 1974
Cooper et al., 1974

Apollo Results

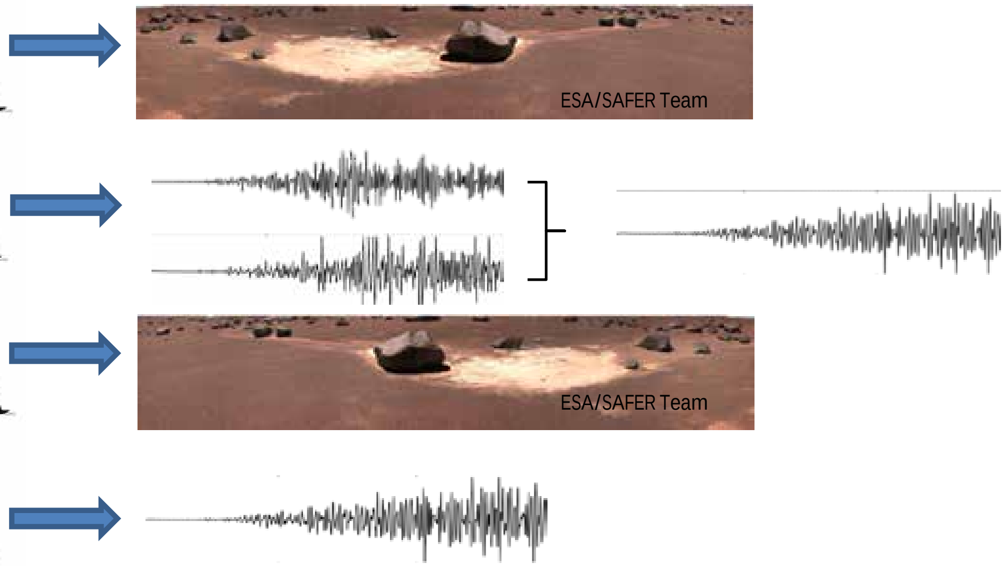


Apollo 14 & 16 Prel. Sci. Rep., 1971, 1972, Cooper et al, 1974

ROBEX Active Seismic Experiment



- Objective:
  Perform active seismic measurements on the lunar surface by using a lander based active seismic source and a mobile sensor
- Architecture:
  Combination of two landed elements and one mobile element



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Why Etna?

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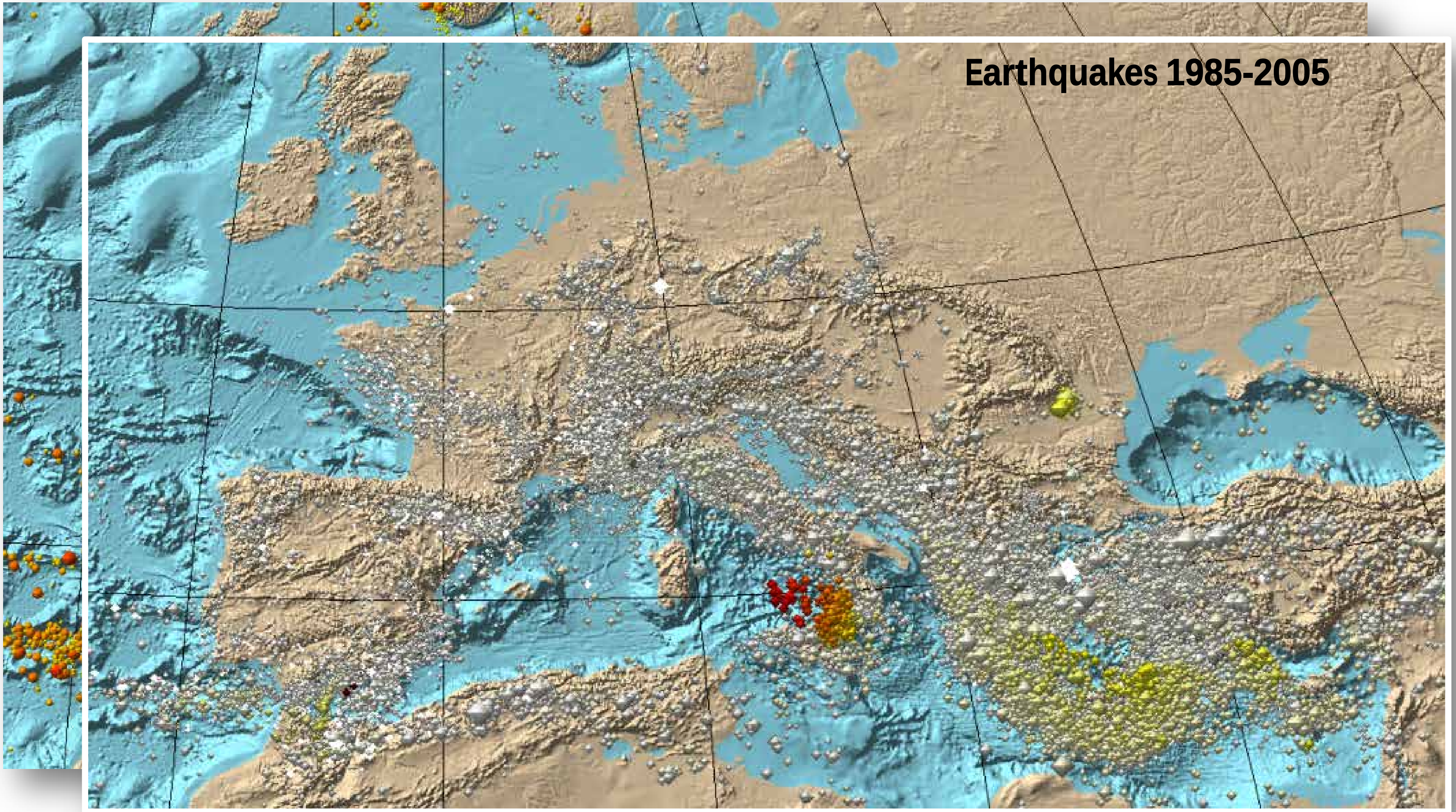
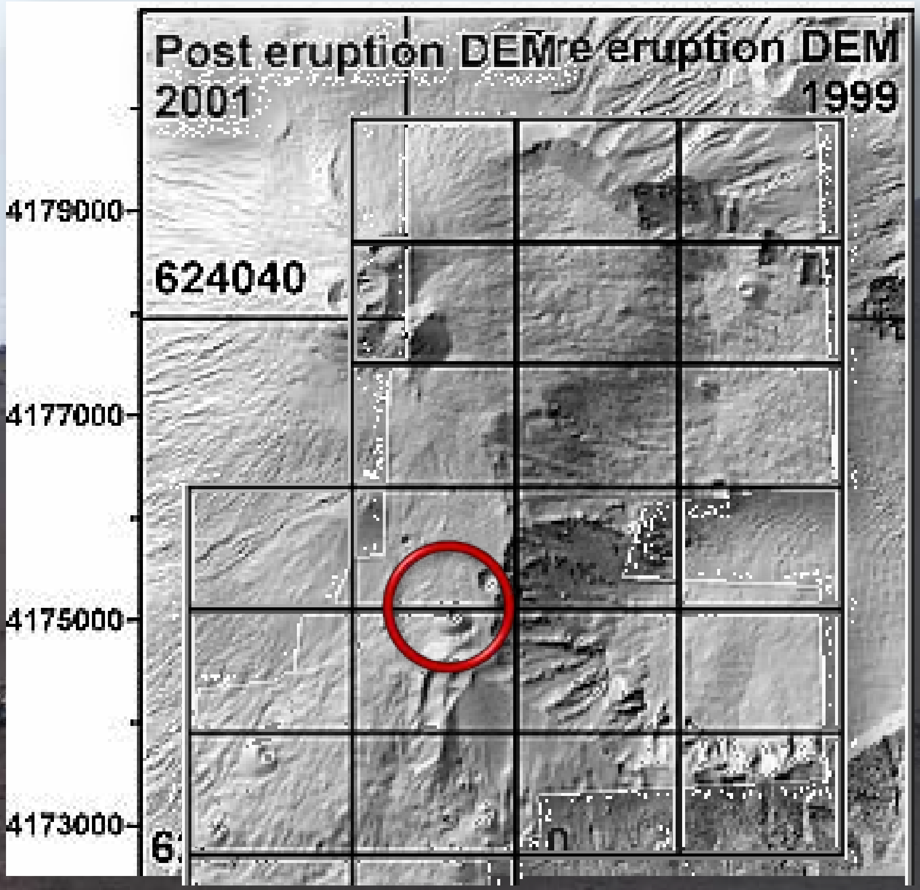
Etna Field Site

Why Etna?



Etna Field Site



Coltelli et al., Analysis of the 2001 lava flow eruption of Mt. Etna from three-dimensional mapping
Volume 112, Issue F2, F02029, 1 JUN 2007 DOI: 10.1029/2006JF000598
http://onlinelibrary.wiley.com/doi/10.1029/2006JF000598/full#jgrf319-fig-0003

Etna Field Site

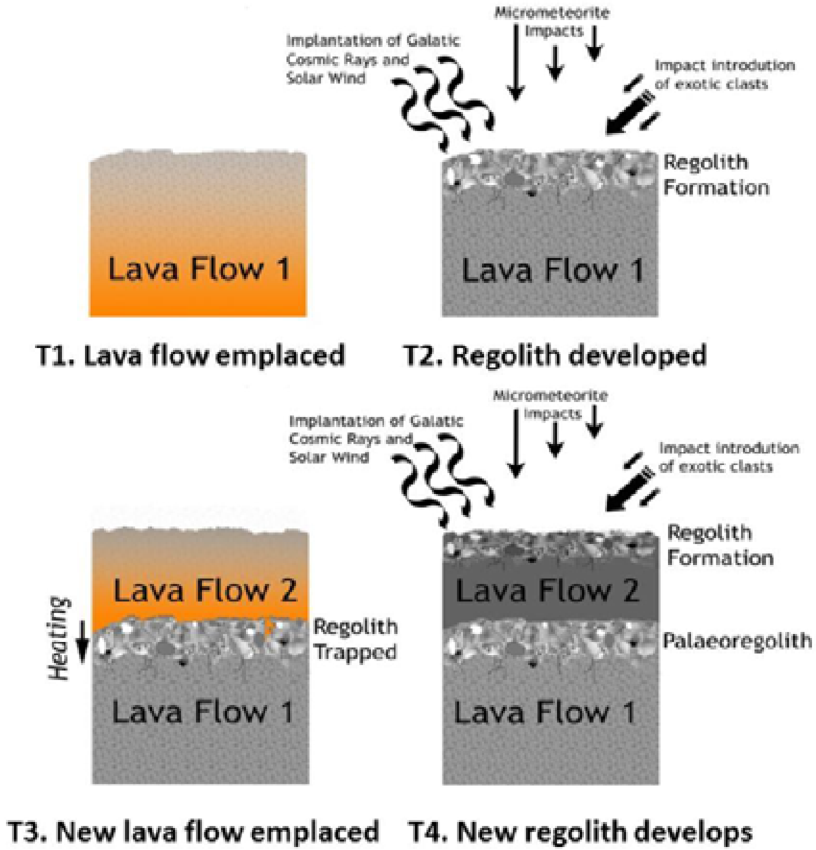
Fig. 5. View from the north-northw
at 2550 m a.s.l. and the 600–700
July. La Montagnola cone is in t
lava flow from the 2700 m vent is
The black portion of the plume contained substantially more juvenile ash than the brown, lithic-rich plume. Ash fallout is predominantly east of the plume (left of the photograph).

Fig. 11. Helicopter view of the Laghetto cone on 9 August. The Valle del Bove rim is on the right upper corner of the photograph, north is on the upper left. Note the two vents on the southern base of the cone, one with a very viscous lava that had flowed east into the Valle del Bove (not active at the time when the photo was taken), and another forming a nearly-circular vent. La Montagnola is on the low right corner of the photograph.

2550 m a.s.l.. This eventually formed the Laghetto cone. The ash plume rising

Calvari & Pinkerton, 2004

Etna Field Site



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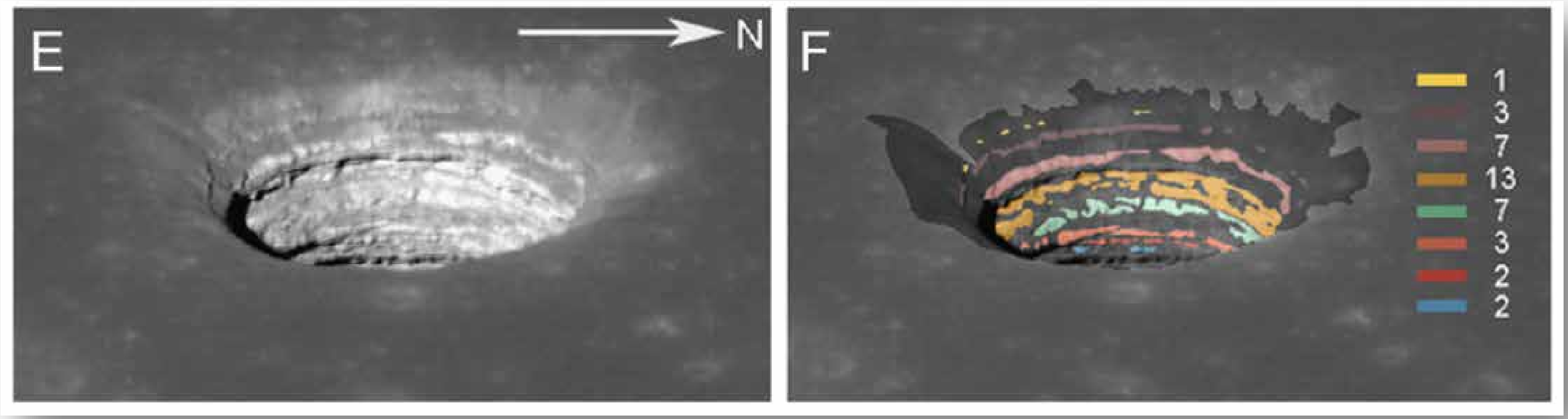
Cisternazza, by the way



Passive Seismic Network

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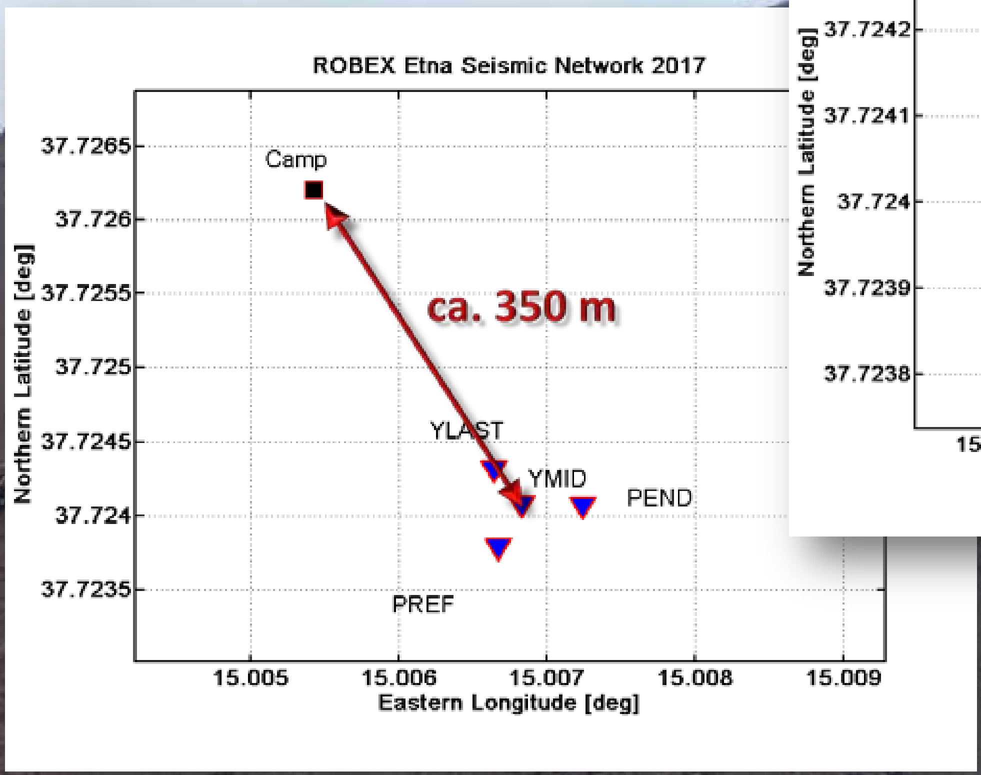
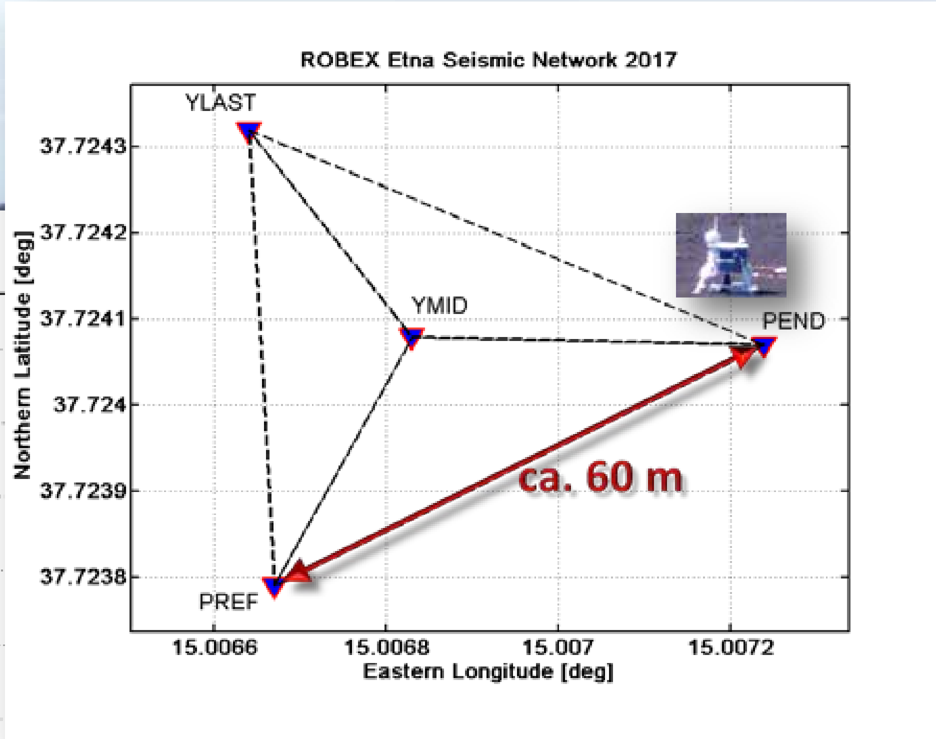
Passive Seismic Network





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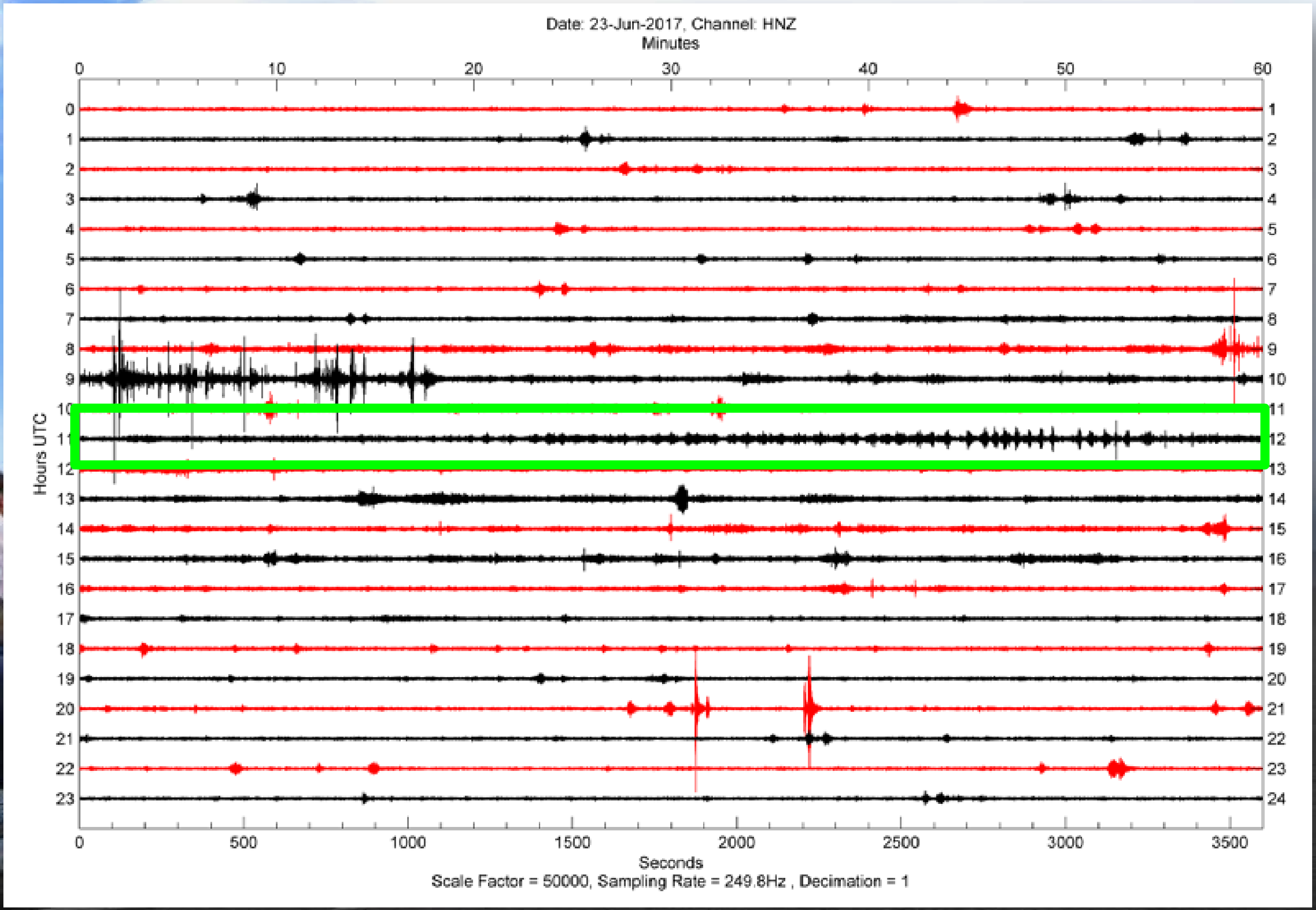
Passive Seismic Network: Data Example



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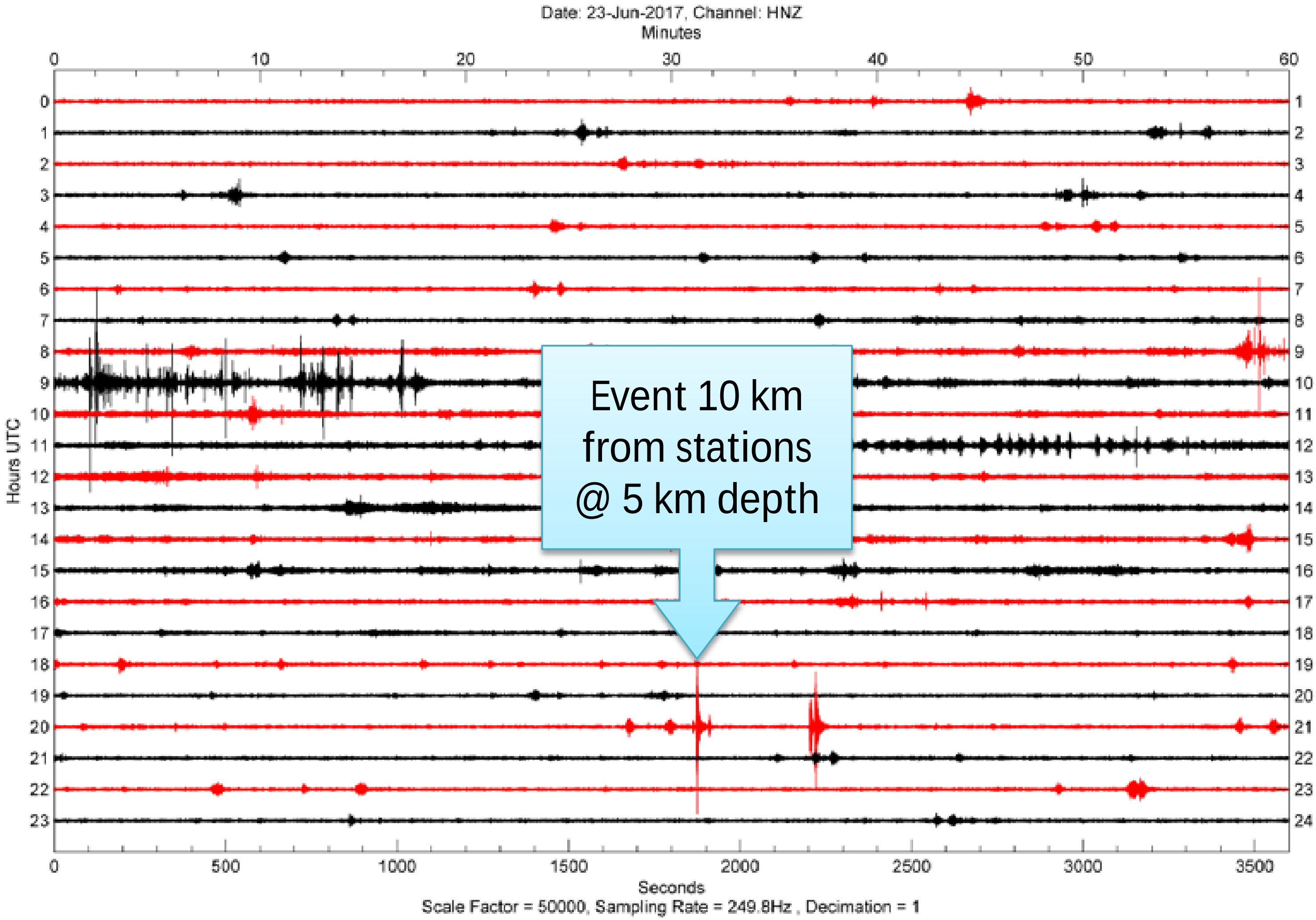
Passive Seismic Network: Data Example



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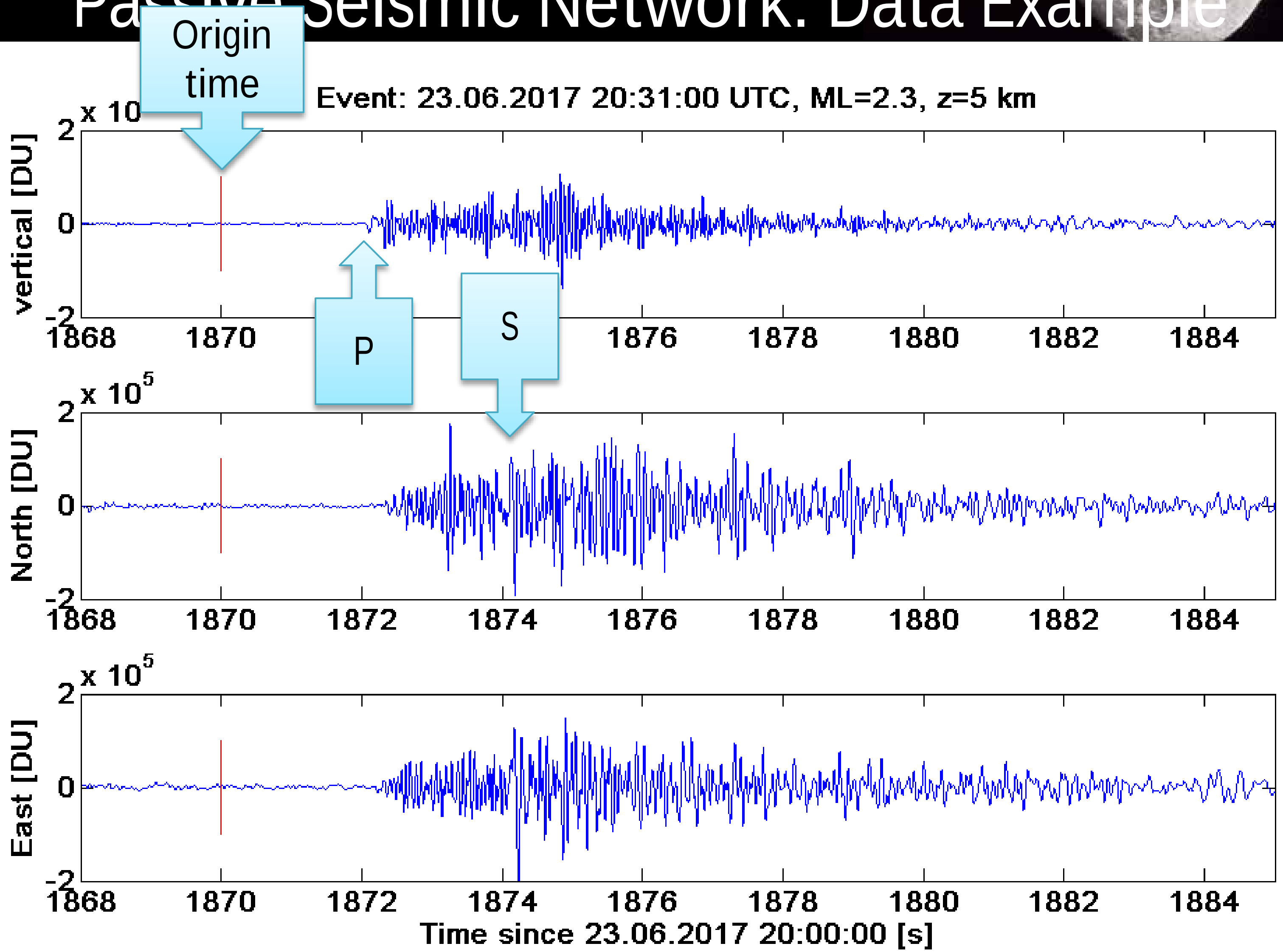
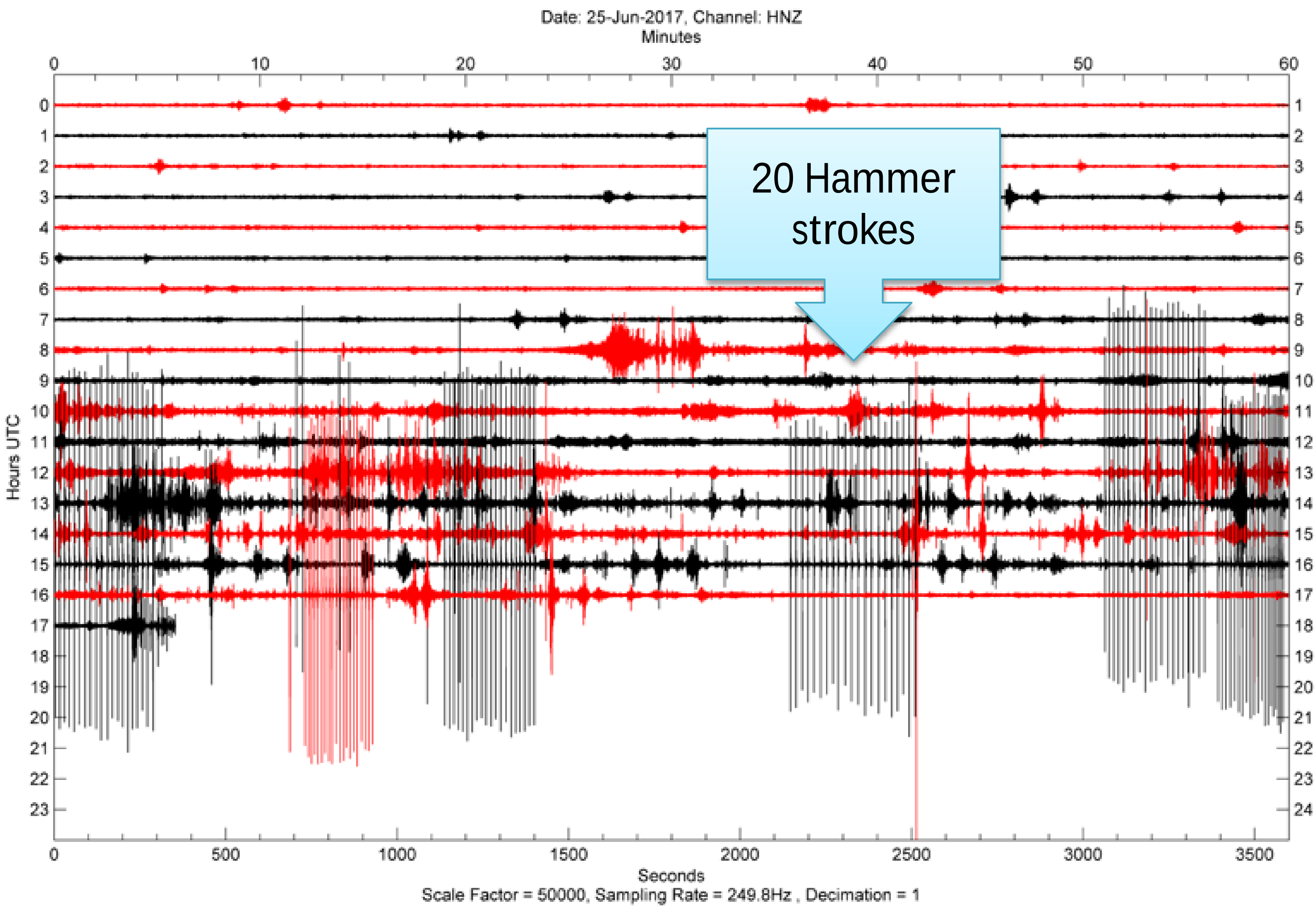


Seismic Profiling



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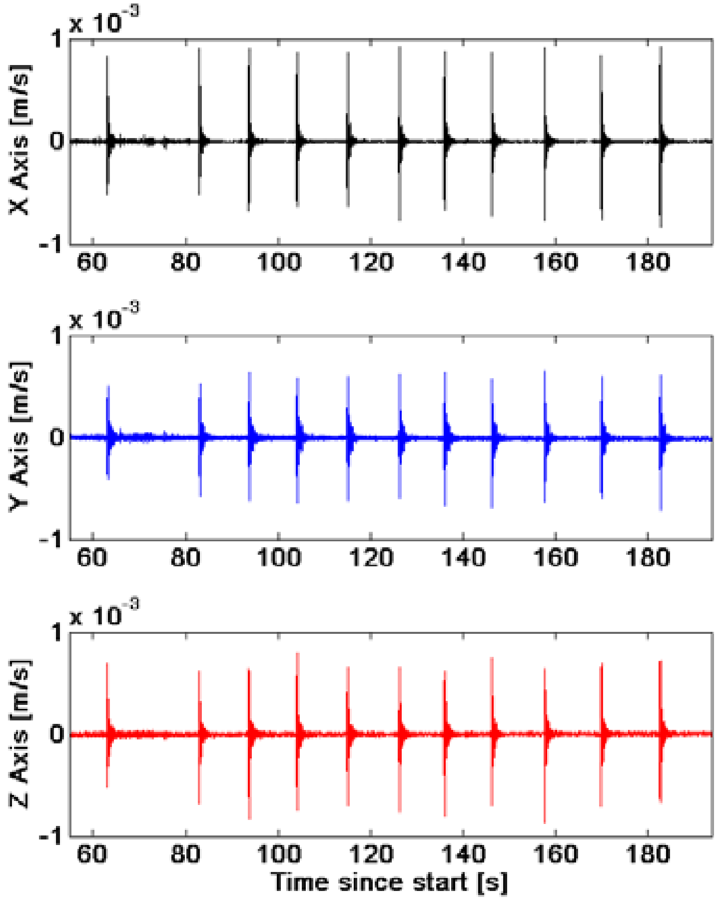

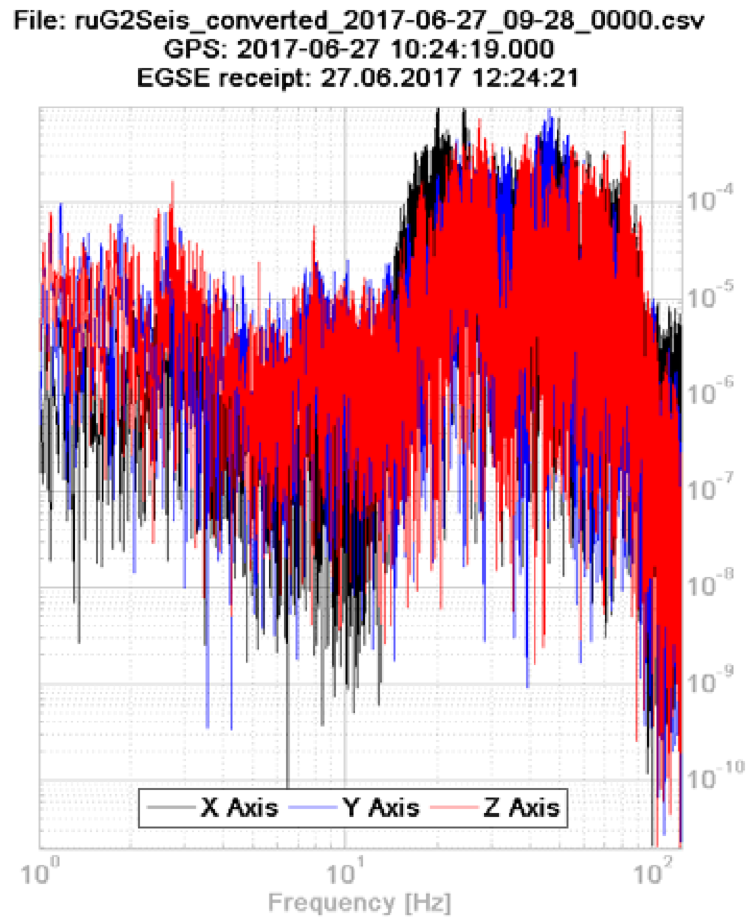

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Seismic Profiling: Data Example

- Station PREF and ruC1 co-located
- First of 20 hammer strokes

Differences similar to having two Lennartz, one buried one on surface